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Aerobic Rice Yield and Nutrient Content as Influenced by Application Coconut Shell Biochar and Farm Yard Manure with NPK Fertilizers

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ABSTRACT

A field experiment was under taken in Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga, to study the combined and individual application of biochar with Farm Yard Manure (FYM) and NPK fertilizers on yield and nutrient content of aerobic rice crop. The experiment was planned with 16 treatments consisting of four levels of biochar at 2, 4, 6 and 8 t ha^{-1} and two levels of FYM at 5 and 10 t ha^{-1} with applied alone and in combinations. The recommended dose of fertilizer (RDF) was applied commonly to all the treatments except absolute control. The treatments were imposed in RCBD design with three replications for each treatment. Significantly higher aerobic rice grain (5784 kg ha^{-1}) and straw (7624 kg ha^{-1}) yield were obtained due to combined application CS-biochar @ 8t ha^{-1} + FYM 10 t ha^{-1}+ RDF (T_{16}) over treatment T_4 (RDF + FYM 10 t ha^{-1}). Nutrient (N, P, K, Ca, Mg, S, Fe, Cu, Zn and Mn) content was significantly higher in the treatments of biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF which was on par with CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF as compared to RDF alone treatment at all the growth stages , grain and straw. Study indicates the necessity of combined application of biochar, FYM and fertilizer for higher growth and yield, reflecting and confirming the improved nutrient availability to aerobic rice.

Keywords Biochar, Nutrient content, Yield, Aerobic rice.

INTRODUCTION

Major challenge in 21st century will be feeding the world's growing population, particularly under the increasing competition for land for extensive agriculture, urban expansion, transport, infrastructure, mining, biodiversity protection and recreation. In addition to this there is effect of global climate change and increased rate of land degradation. Increasing food production while per capita land resources are decreasing will require increased intensity of crop production, which may have undesirable consequences on ecosystem when we achieved through increased use of agrochemical and irrigation. It is scathing that sustainable agriculture practices like, focusing on efficient use of land, water, crop residues, nutrients,

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protection of soil resources and minimizing adverse impacts on environment is present and future challenge for mankind.

Rice is the one of the major staple food for more than half of the world population and is cultivated in 113 countries of the world. India contributes world largest acreage of rice cultivation with an area of 43 million hectares (Babu 2014). “International year of rice – 2004 AD” had the slogan “Rice is life” - means rice as way of life, the source of livelihood. Irrigated lowland rice is consequently the most important agricultural ecosystem in Asia (Subramanian *et al.* 2008). Wetlands are considered to be of critical importance in global carbon cycle. Compared to uplands or arable soils, relatively little research efforts has been devoted to modelling organic matter in wet land soils, although rice is a major food crops under wetland which contributes handsomely to global rice supply. Water shortage in many rice growing areas is promoting a search for production systems that use less water to produce rice. Aerobic rice systems, where the crop is established via direct seeding in un-puddled, non-flooded fields and managed intensively as an upland crop are among the most promising approaches of water saving (Subramanian *et al.* 2008). Achieving higher rice grain yields under irrigated aerobic conditions requires better weed management practices and effective utilization of resources that reduce the cost of cultivation. Hence, the research to improve aerobic rice yield should focus primarily on efficient nutrient and moisture management to make rice cultivation more efficient in terms of returns on farmer investments. A yield decline under aerobic conditions was observed when aerobic rice was continuously grown and decline was greater in the dry season than in the wet season. Therefore to improve aerobic rice yield the focus should be on sustainable management of soil to improve the moisture and nutrient availability (Sharat *et al.* 2016).

In recent years, biochar has emerged as an organic amendment with mineral nutrient elements and hold a promise to improve the soil quality and yield of crops. The biochar is found to have positive impact on soil fertility, resulting in an increase in crop yield without causing hazard to soil and water environment. Hence addition of biochar with Farm Yard Manure (FYM) and NPK fertilizers to soils has attracted widespread attention as a method to improve soil fertility and productivity. Biochar and FYM application increased soil carbon sequestration and improve soil quality because of the vital role that carbon plays in chemical, biological and physical soil processes and many interfacial interactions. Keeping these points in view, an experiment entitled “Aerobic Rice Yield and Nutrient Content as influenced by application Coconut Shell Biochar and Farm Yard Manure with NPK Fertilizers” was carried out during summer season of 2018 in Typic Haplustalf sandy loam soil.

MATERIALS AND METHODS

An experiment was under taken in the Department of Soil Science and Agricultural Chemistry, College of Agriculture located at Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga, belongs to Southern Transition Agro-climatic Zone (Zone - 7) of Karnataka. The research station is situated at 14^{o}0’ to 14^{o}1’ North latitude and 75^{o} 40’ to 75^{o} 42’ east longitude with an altitude of 650 meters above the mean sea level. The average rainfall of the zone is 873.40 mm. Initial characterization of soil experimental site indicated that soil had a acidic pH of 5.88, EC of 0.22 dSm^{-1} with organic carbon content of 4.68 g kg^{-1} and CEC of 14.43 cmol (p+) kg^{-1}. Further, the soil was low in available nitrogen (213.35 kg ha^{-1}), high in available phosphorus status (58.17 kg ha^{-1}) and medium in available potassium status (157.63 kg ha^{-1}). The exchangeable Ca and Mg were 2.85 and 1.74 (cmol (p+) kg^{-1}), Available sulfur was 11.59 ppm and all the DTPA extractable micronutrients were above the critical limits (Fe- 12.18, Mn-2.58, Zn-2.18 and Cu-1.13 ppm). The soil belongs to the taxonomic class of *Typichaplustalf* with sandy loam texture. The experiment was planned with 16 treatments consisting of four levels of biochar at 2, 4, 6 and 8 t ha^{-1} and two levels of FYM at 5 and 10 t ha^{-1} with applied alone and in combinations. The recommended dose of fertilizer (RDF) was applied commonly to all the treatments except absolute control. The treatments were imposed in RCBD design with three replications for each treatment. The aerobic rice (MAS 946-1 or Sharada) was taken up as a testing crop. The details as follows

T_1: Absolute control, T_2: 100:50:50 NPK kg ha^{-1}(Only RDF), T_3:FYM @ 5 t ha^{-1}, T_4: FYM @ 10 t ha^{-1} (POP), T_5: CS - Biochar@ 2 t ha^{-1}, T_6: CS - Biochar @ 4 t ha^{-1} T_7: CS - Biochar @ 6 t ha^{-1}, T_8: CS - Biochar @ 8 t ha^{-1}, T_9: CS - Biochar @ 2 t ha^{-1} + FYM @ 5 t ha^{-1}
T_{10}: CS - Biochar @ 4 t ha^{-1} +FYM @ 5 t ha^{-1}
T_{11}: CS - Biochar @ 6 t ha^{-1} + FYM @ 5 t ha^{-1}
T_{12}: CS - Biochar @ 8 t ha-1 + FYM @ 5 t ha^{-1}
T_{13}:CS-Biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1}
T_{14}: CS - Biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1}
T_{15}:C - Biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1}
T_{16}: CS - Biochar @ 8 t ha^{-1} +FYM @ 10 t ha^{-1}
Note: CS: Coconut shell,
RDF: Recommended dose of fertilizer

Observations on and yield parameters were recorded on randomly selected five plants from each net plot and tagged for recording the observations. Aerobic rice vegetative samples, grain and straw were subjected to nutrient content analysis at 30, 60, 90 days after sowing (DAS) and at harvest. The experimental data obtained were subjected to statistical analysis adopting Fisher's method of analysis of variance as out lined by Gomez and Gomez (1984). The level of significance used in F test was at 5%. Critical difference (CD) values are given for the data at 5% level of significance, wherever the F test was significant.

RESULTS AND DISCUSSION

Grain and straw yield (q ha^{-1}) and harvest index of aerobic rice crop

Significant increase in grain and straw yield was recorded with the combined application of CS-biochar (6 to 8 t ha^{-1}) and FYM (10 t ha^{-1}) with RDF (100:50:50 kg NPK ha^{-1}) treatments (Table 1). However, significantly higher aerobic rice grain (5784 kg ha^{-1}) and straw (7624 kg ha^{-1}) yield were obtained due to combined application CS-biochar @ 8t ha^{-1} + FYM 10 t ha^{-1}+ RDF (T_{16}). This might be due to increase in rate of CS-biochar which increases the nutrient supply and moisture content in soil. Increase in crop productivity with application of CS-biochar can be attributed to increased CEC of soil, pH and base saturation, available P, nutrient retention and

Table 1. Effect of levels of biochar on yield parameters and yield of aerobic rice at harvest.

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (HI)
T_1	1602	2022	0.44
T_2	4314	5394	0.44
T_3	4708	5938	0.44
T_4	5198	6528	0.44
T_5	4383	5485	0.44
T_6	4411	5512	0.44
T_7	4621	5769	0.44
T_8	4710	5879	0.45
T_9	4778	5933	0.45
T_{10}	4849	6045	0.45
T_{11}	4924	6241	0.44
T_{12}	5106	6432	0.43
T_{13}	5318	6741	0.44
T_{14}	5458	6971	0.44
T_{15}	5793	7230	0.44
T_{16}	6184	7724	0.43
SEm±	191	249	0.01
CD (p=0.05)	546	712	NS

increased plant-available water. Ultimately it might have increased the grain and straw yield of aerobic rice. Higher grain and straw yield in aerobic rice could also be attributed to better total uptake of essential nutrients and its translocation to economic parts as well as improvement in yield attributing characters like number of panicles per hill, number of grains per hill and 1000 seeds grain weight. Such responses with application rates were reported by Van Zwieten *et al.* (2010).

Primary nutrients content (%) at different growth stages

Nitrogen, phosphorus and potassium content by aerobic rice plant parts differed significantly by different levels CS-biochar and FYM application at all the growth stages, except at 30 DAS (Table 2).

Significantly higher nitrogen content was noticed in the treatment CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF (T_{16}) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF (T_{15}) (1.306 and 1.272 %, respectively) which was on par with biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF (1.194 %) as compared to RDF treatment (1.128 %) at 60 DAS. Even, at 90 DAS Significantly higher nitrogen content was recorded in the treatment of CS-biochar @ 8 t

Table 2. Effect of levels of biochar on primary nutrients content of aerobic rice plant at different growth stages.

Treatments	N (%)			P (%)			K (%)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_1	0.886	1.002	1.031	0.127	0.196	0.336	0.539	0.681	1.083
T_2	1.132	1.128	1.291	0.208	0.245	0.394	0.648	0.803	1.245
T_3	1.159	1.174	1.392	0.236	0.269	0.410	0.676	0.839	1.277
T_4	1.181	1.189	1.428	0.250	0.309	0.438	0.742	0.850	1.341
T_5	1.140	1.125	1.295	0.208	0.241	0.392	0.621	0.794	1.235
T_6	1.143	1.152	1.378	0.253	0.246	0.408	0.659	0.829	1.257
T_7	1.152	1.161	1.396	0.233	0.251	0.413	0.682	0.833	1.279
T_8	1.155	1.162	1.399	0.232	0.265	0.425	0.718	0.837	1.281
T_9	1.161	1.178	1.309	0.225	0.269	0.429	0.711	0.842	1.286
T_{10}	1.166	1.184	1.415	0.247	0.286	0.436	0.734	0.845	1.314
T_{11}	1.178	1.183	1.416	0.249	0.302	0.432	0.736	0.846	1.332
T_{12}	1.163	1.190	1.422	0.243	0.308	0.441	0.739	0.869	1.337
T_{13}	1.189	1.179	1.462	0.258	0.301	0.446	0.755	0.882	1.354
T_{14}	1.185	1.194	1.548	0.258	0.333	0.463	0.778	0.929	1.408
T_{15}	1.204	1.272	1.663	0.259	0.357	0.484	0.775	0.946	1.431
T_{16}	1.191	1.306	1.753	0.269	0.343	0.508	0.782	0.957	1.486
SEm±	0.08	0.041	0.057	0.04	0.010	0.015	0.08	0.036	0.049
CD (p=0.05)	NS	0.114	0.162	NS	0.031	0.044	NS	0.104	0.141

ha^{-1} + FYM @ 10 t ha^{-1} with RDF (1.753%) and were on par with CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF (T_{15}) which recorded 1.663 % than in RDF treatment (1.291 %), Significantly higher phosphorus content (0.343%) at 60 DAS was recorded in the treatment T_{16} (CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF (0.357 %) which was on par with T_{14} (CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF) (0.333 %) as compared to RDF alone treatment (0.245 %). Even, at 90 DAS, phosphorus content was significantly higher in the treatments of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF (0.508 %) which was on par with CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} with RDF (0.484 %) as compared to RDF alone treatment (0.394 %). Higher potassium content values viz., 0.957,0.946, 0.929, and 0.882 % was recorded in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 4 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF, CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF and it was on par with CS- biochar @ 8 t ha^{-1} + FYM @ 5t ha^{-1} + RDF (0.869 %) as compared to RDF treatment (0.803 %) at 60 DAS. At 90 DAS, higher potassium content was recorded in CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (1.486 %) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (1.431 %) and it was on par with CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} and CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (1.408 and 1.354 %, respectively) over RDF alone (1.245 %) treatment.

Primary content in grain and straw (%)

The data on nitrogen, phosphorus and potassium content in grain and straw by aerobic rice is presented in Table 3. The treatments receiving application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar (CS) @ 4 t ha^{-1} + FYM @ 10 t ha^{-1}+ RDF, recorded significantly higher nitrogen content in grains (1.148, 1.142 and 1.136 %, respectively) and these were on par with CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (1.102) as compared to the treatment, T_2 (RDF alone) which recorded 0.871%.

Nitrogen content differed in straw significantly by different due to combined application biochar and FYM over absolute control and RDF treatments. However, higher nitrogen content in straw was resulted in CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.596 %) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.592 %), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.583 %), CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.574 %),

Table 3. Effect of levels of biochar on primary nutrients content in grain and straw of aerobic rice at harvest.

Treatments	N (%)		P (%)		K (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1	0.719	0.277	0.199	0.186	0.719	0.873
T_2	0.871	0.459	0.264	0.208	0.858	0.981
T_3	0.977	0.491	0.292	0.275	0.893	1.012
T_4	1.029	0.538	0.320	0.298	0.911	1.041
T_5	0.886	0.472	0.265	0.218	0.849	1.005
T_6	0.903	0.472	0.292	0.256	0.864	1.008
T_7	0.973	0.485	0.308	0.261	0.886	1.011
T_8	0.975	0.506	0.311	0.282	0.908	1.014
T_9	0.986	0.533	0.316	0.284	0.911	1.039
T_{10}	1.022	0.544	0.319	0.288	0.914	1.055
T_{11}	1.028	0.548	0.321	0.281	0.938	1.059
T_{12}	1.034	0.567	0.345	0.297	0.941	1.061
T_{13}	1.102	0.574	0.348	0.304	0.981	1.146
T_{14}	1.136	0.583	0.357	0.306	0.989	1.153
T_{15}	1.142	0.592	0.363	0.319	1.012	1.167
T_{16}	1.148	0.596	0.368	0.327	1.042	1.170
SEm±	0.037	0.018	0.007	0.009	0.035	0.044
CD (p=0.05)	0.109	0.051	0.021	0.026	0.100	0.125

CS-biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF and CS-biochar @ 6 t ha^{-1} + FYM @ 5 t ha^{-1} (0.567 and 0.548% respectively) and over rest of the treatments.

Similar trend was followed with respect to phosphorus content in grain and straw. Significantly higher phosphorus content in grain and straw was recorded in treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.368 and 0.327 %, respectively) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.363 and 0.319 %, respectively), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.357 and 0.306 %, respectively), these were on par with the treatment, T_{13} (CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF) which recorded 0.348 and 0.304 % respectively as compared to RDF treatment (0.264 and 0.208 % respectively).

The potassium content in grain and straw increased with increased levels of CS-biochar with FYM. Application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF recorded significantly higher potassium content in grain and straw (1.042 and 1.170 % respectively) and it was followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (1.012 and 1.167 %, respectively), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.984 and 1.153 % respectively) and CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.981 and 1.146 % respectively) as compared to RDF treatment (0.858 and 0.981 % respectively).

Significant increase in primary nutrients (N, P and K) content in different plant parts of aerobic rice was recorded with the application of combined application of coconut shell biochar (6 to 8 t ha^{-1}) and FYM (10 t ha^{-1}) with RDF treatments. This could be attributed to the fact that besides acting as an amendment, biochar also provides all the essential nutrients in sufficient quantities for better uptake. Results of enhanced uptake of nutrients due to the application of biochar were reported by Gebermedihin *et al.* (2015). Addition of bio-char to soil has shown definite increases in the availability of major cations and phosphorus as well as in total nitrogen and phosphorus concentrations Elramady *et al.* (2014) and Babu (2014).

Secondary nutrients content (%) at different growth stages

Calcium, magnesium and sulfur content differed significantly by different levels biochar and FYM application at all the growth stages, except at 30 DAS (Table 4). Significantly higher calcium content in grain at both 60 and 90 DAS was observed in CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.687 and 1.208 %, respectively) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.658 and 1.165 %) which was on par with CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.625 and 1.121 %) over all other treatments. However, lower calcium content was noticed in recommended dose of fertilizer applied treatments (0.538 and 0.896 % respectively).

Similar trend was followed with respect to magnesium content at 60 and 90 DAS. Significantly higher magnesium content was recorded in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.392 and 0.566 %, respectively) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.386 and 0.545% respectively) which was on par with CS-biochar @ 4t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.352 and 0.521% respectively) over rest of the treatments recorded significantly lower Mg content in plant at both 60 and 90 DAS.

Table 4. Effect of levels of biochar on secondary nutrients content of aerobic rice plant at different growth stages.

Treatments	Ca (%)			Mg (%)			S (%)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_1	0.168	0.351	0.687	0.142	0.218	0.339	0.074	0.148	0.192
T_2	0.292	0.538	0. 896	0.183	0.296	0.436	0.109	0.194	0.294
T_3	0.296	0.595	1.015	0.235	0.319	0.489	0.118	0.250	0.340
T_4	0.323	0.604	1.042	0.271	0.338	0.504	0.133	0.253	0.344
T_5	0.235	0.526	1.016	0.174	0.277	0.429	0.093	0.209	0.296
T_6	0.259	0.552	1.021	0.177	0.273	0.450	0.091	0.213	0.298
T_7	0.271	0.572	1.029	0.197	0.285	0.452	0.104	0.217	0.318
T_8	0.294	0.583	1.036	0.219	0.306	0.473	0.106	0.231	0.331
T_9	0.305	0.591	1.037	0.228	0.318	0.479	0.103	0.228	0.336
T_{10}	0.317	0.597	1.041	0.241	0.320	0.487	0.115	0.241	0.340
T_{11}	0.312	0.600	1.053	0.246	0.321	0.498	0.135	0.244	0.342
T_{12}	0.316	0.602	1.056	0.253	0.333	0.496	0.138	0.248	0.343
T_{13}	0.338	0.610	1.079	0.266	0.345	0.499	0.149	0.256	0.345
T_{14}	0.361	0.625	1.121	0.278	0.352	0.521	0.134	0.265	0.359
T_{15}	0.367	0.658	1.165	0.304	0.386	0.545	0.146	0.268	0.371
T_{16}	0.384	0.684	1.208	0.307	0.392	0.566	0.159	0.271	0.394
SEm±	0.04	0.022	0.039	0.054	0.015	0.020	0.015	0.009	0.029
CD (p=0.05)	NS	0.062	0.113	NS	0.044	0.059	NS	0.028	0.082

Sulfur content in plant parts of aerobic rice was significantly higher values of 0.271, 0.268, 0.265, 0.56, 0.253, 0.250 and 0.248 % sulfur content was recorded in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (T_{16}), CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (T_{15}), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (T_{14}), CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (T_{13}), FYM @ 10 t ha^{-1} (T_4), FYM @ 5 t ha^{-1} (T_3) and CS-biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1} (T_{12}), respectively as compared T_2 (RDF treatment) (0.194%) and remaining treatments were on par with each other, at 60 DAS. Biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1}, applied treatment recorded significantly higher sulfur content (0.394 %) at 90 DAS as compared to RDF treatment (0.294 %) and remaining treatments were on par with each other except T_6, T_5 and T_1.

Secondary content in grain and straw (%)

The data on calcium, magnesium and sulfur content in grain and straw by aerobic rice is presented in Table 5 Significantly higher calcium content in grains was analyzed in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF and CS-biochar @ 6 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF (0.796, 0.758, 0.721, 0.683, 0.657 and 0.0.652 %, respectively) as compared to RDF applied treatment (0.519 %). Even, in straw higher Ca content noticed due application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF recorded significantly higher calcium content in straw (0.583 %) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.579 %), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.574 %), CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.559 %) and these was on par with CS-biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF (0.534 %). However, low calcium content was noticed in application of recommended dose of fertilizer (100:50:50 NPK kg ha^{-1}), biochar @ 2 t ha^{-1} and absolute control (0.446, 0.443 and 0.377 %, respectively).

Significantly higher magnesium content in grain was recorded in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.513 %) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.497 %) which was on

Table 5. Effect of levels of biochar on secondary nutrients content in grain and straw of aerobic rice at harvest.

Treatments	Ca (%)		Mg (%)		S (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1	0.434	0.377	0.244	0.179	0.105	0.092
T_2	0.519	0.446	0.374	0.227	0.167	0.169
T_3	0.566	0.491	0.406	0.332	0.218	0.203
T_4	0.647	0.530	0.432	0.362	0.222	0.208
T_5	0.521	0.443	0.382	0.228	0.175	0.152
T_6	0.547	0.462	0.401	0.255	0.183	0.155
T_7	0.574	0.469	0.414	0.266	0.204	0.161
T_8	0.608	0.471	0.423	0.323	0.206	0.180
T_9	0.623	0.461	0.428	0.328	0.209	0.183
T_{10}	0.641	0.503	0.426	0.341	0.212	0.202
T_{11}	0.652	0.526	0.427	0.345	0.215	0.207
T_{12}	0.657	0.534	0.430	0.354	0.218	0.193
T_{13}	0.683	0.559	0.465	0.376	0.233	0.212
T_{14}	0.721	0.574	0.479	0.383	0.260	0.215
T_{15}	0.758	0.579	0.497	0.401	0.265	0.223
T_{16}	0.796	0.583	0.513	0.407	0.271	0.239
SEm±	0.051	0.018	0.015	0.015	0.008	0.007
CD (p=0.05)	0.145	0.051	0.044	0.043	0.023	0.020

par with treatment received CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.479 %) as compared to recommended dose of fertilizer (100:50:50 NPK kg ha^{-1}) applied treatment (0.374 %). Even, in straw significantly higher values of 0.407, 0.401, 0.383 and 0.376% of magnesium content in straw was recorded in CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF and CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, applied treatments, respectively and over RDF treatment (0.227 %).

Significantly higher sulfur content in grains was analyzed in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF which was on par with CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (0.271, 0.265 and 0.260 %, respectively) as compared to recommended dose of fertilizer (100:50:50 NPK kg ha^{-1}) applied treatment (0.167 %). Even, higher straw S content was registered with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF recorded significantly higher sulfur content in straw (0.239%) over all other treatments. However, lower sulfur content was observed in CS-biochar @ 4 t ha^{-1}, biochar @ 2 t ha^{-1}, RDF alone and absolute control treatments (0.155, 0.152,0.169 and 0.092 %, respectively).

Micronutrients content (mg kg^{-1}) at different growth stages

Similar trend was followed with respect to iron, manganese zinc and copper content differed significantly by different levels CS-biochar and FYM application at all the growth stages, except at 30 DAS (Table 6). Significantly higher iron content was recorded at both 60 and 90 DAS, in the treatment CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (258.96 and 267.28 mg kg^{-1}, respectively) it was followed by CS-biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF (258.47 and 265.78 mg kg^{-1}, respectively), CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (250.43 and 264.57 mg kg^{-1}, respectively), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (251.20 and 264.19 mg kg^{-1}, respectively), CS-biochar @ 6 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF (250.21 and 259.47 mg kg^{-1}, respectively) and CS-biochar @ 4 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF (250.18 and 259.47 mg kg^{-1}, respectively) and theses were on par with each other as compared to recommended dose of fertilizer (161.20 and 209.24 mg kg^{-1}, respectively).

Mn content in different plant parts of aerobic rice was significantly influenced by CS-biochar and FYM applied at the level of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF recorded significantly higher manganese content (319.71 mg kg^{-1}) and it was followed by CS-biochar @ 6t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (305.26 mg kg^{-1}), b CS-iochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (304.06 mg kg^{-1}), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (304.06 mg kg^{-1}), CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (305.12 mg kg^{-1}) and biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF (301.37 mg kg^{-1}). However, significantly higher manganese content at 90 DAS was observed in application of biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (467.93 mg kg^{-1}) followed by biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (461.13 mg kg^{-1}), biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (450.26 mg kg^{-1}), biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (445.71 mg kg^{-1}) and these were on par with biochar @ 8 t ha^{-1} + FYM @ 5 t ha^{-1} + RDF (438.23 mg kg^{-1}) over other treatments.

Similar trend was followed with respect to zinc

Table 6. Effect of levels of biochar on micronutrients content of aerobic rice plant at different growth stages.

Treatments	Fe(mg kg^{-1})			Mn(mg kg^{-1})			Zn(mg kg^{-1})			Cu(mg kg^{-1})		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_1	68.15	97.56	133.00	101.26	199.47	233.12	21.37	39.63	79.15	11.13	18.37	29.92
T_2	77.24	161.20	209.24	152.42	208.31	315.61	44.23	56.23	81.67	16.97	25.15	35.52
T_3	80.45	188.27	237.46	166.34	216.83	323.87	45.13	66.34	84.11	28.14	40.12	49.17
T_4	83.56	219.73	238.58	170.64	229.71	327.12	46.27	68.97	86.62	30.45	43.21	50.12
T_5	77.53	228.37	233.27	142.61	210.16	317.26	45.26	55.83	82.41	23.28	37.51	48.47
T_6	78.64	228.71	236.41	145.38	215.36	347.19	39.96	56.21	84.37	23.87	38.75	49.97
T_7	80.73	234.61	236.61	146.20	215.47	372.45	40.52	58.23	86.57	24.69	40.89	50.46
T_8	82.31	238.26	240.00	147.18	218.36	398.09	44.23	59.98	86.21	26.00	41.75	52.18
T_9	82.13	248.43	255.43	181.67	285.12	402.18	44.27	59.17	87.09	26.38	42.83	52.65
T_{10}	82.71	250.18	257.22	183.26	294.97	412.22	44.31	59.82	92.28	26.41	43.72	54.19
T_{11}	84.61	250.21	259.47	184.69	298.19	425.17	46.23	62.07	92.41	27.69	44.83	57.82
T_{12}	85.23	258.47	265.78	184.79	301.37	438.23	45.78	63.82	92.47	27.67	44.98	59.07
T_{13}	85.10	248.86	253.87	178.24	304.12	445.71	45.21	65.72	92.16	29.86	48.23	62.82
T_{14}	85.15	251.20	264.19	187.43	304.06	450.26	46.03	68.81	93.07	31.43	48.67	65.18
T_{15}	87.15	250.43	264.57	187.67	305.26	461.13	47.11	76.17	98.43	31.98	49.52	69.65
T_{16}	88.24	258.96	267.28	190.23	319.47	467.93	57.21	78.25	102.41	32.33	50.87	72.12
SEm±	4.47	5.74	8.54	8.13	9.23	14.53	8.94	2.15	3.19	6.26	1.58	2.01
CD (p=0.05)	NS	16.58	24.66	NS	26.66	41.96	NS	6.22	9.22	NS	4.57	5.80

content at 60 and 90 DAS. Significantly higher zinc content was recorded in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (78.25 and 102.41 mg kg^{-1}, respectively) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (76.17 and 98.43 mg kg^{-1}, respectively and rest of the treatments recorded significantly lower Mg content in plant at both 60 and 90 DAS.

Higher copper content at 60 DAS (50.87 mg kg^{-1}) was observed with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF recorded significantly and it was followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (49.52 mg kg^{-1}), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (48.67 mg kg^{-1}) which was on par with CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF which recorded 48.23 mg kg^{-1} of copper in aerobic rice crop as compared to RDF applied treatment (25.15 mg kg^{-1}). Significantly higher copper content was recorded in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (72.12 mg kg^{-1}) followed by biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (69.65 mg kg^{-1}) and rest of the treatments recorded significantly lower Cu content in plant at both 90 DAS.

Micronutrients content in grain and straw (mg kg^{-1})

The data on iron, manganese, zinc and copper content in grain and straw by aerobic rice is presented in Table 7. Significantly higher iron content in grain was recorded in CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (104.83 mg kg^{-1}) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (100.12 mg kg^{-1}) which was on par with CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (97.95 mg kg^{-1}) and rest of the treatments were significantly on par with each other. However, application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF recorded significantly higher iron content in straw (261.36 mg kg^{-1}) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF, CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF and CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (258.12, 251.48 and 248.83 mg kg^{-1}, respectively). However lower values was resulted in absolute control (89.26 mg kg^{-1}).

The trend of manganese content in grain and straw followed similar pattern. Significantly higher manganese content in grain and straw was analyzed in the treatments with application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (138.36 and 435.31 mg kg^{-1}, respectively) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (133.97 and 434.96 mg kg^{-1}, respectively) which was on par with treatment received CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF which recorded 125.23 and 392.00 mg kg^{-1}, respectively) and rest of the treatments were significantly on par with each other. However, treatments

Table 7. Effect of levels of biochar on micronutrients content in grain and straw of aerobic rice at harvest.

Treatments	Fe(mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})		Cu (mg kg^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	50.28	89.26	84.10	268.21	37.33	67.78	26.29	18.09
T_2	67.23	208.00	98.07	317.37	42.19	71.38	38.23	26.64
T_3	88.00	219.26	98.26	348.89	48.16	76.43	42.26	30.97
T_4	91.00	223.78	118.89	379.28	50.22	78.08	45.29	33.73
T_5	67.16	205.12	88.14	349.35	41.00	72.93	38.67	30.21
T_6	68.87	207.36	90.56	359.03	41.33	73.47	40.11	30.29
T_7	71.15	210.25	92.23	359.71	42.11	74.08	41.33	31.37
T_8	72.24	211.23	92.53	371.13	42.67	75.21	43.00	32.13
T_9	88.05	219.10	98.26	360.21	48.23	78.24	43.23	32.23
T_{10}	90.16	223.10	98.93	360.63	50.09	80.30	44.78	32.48
T_{11}	90.57	230.86	112.34	363.58	50.96	81.00	45.01	33.16
T_{12}	91.19	232.08	118.52	376.37	51.21	81.27	45.27	33.67
T_{13}	94.21	248.83	108.96	386.56	52.89	81.93	47.12	34.21
T_{14}	97.95	251.48	125.23	392.00	55.17	83.57	47.26	34.02
T_{15}	100.12	258.12	133.97	434.96	56.13	87.17	48.00	35.63
T_{16}	104.83	261.36	138.36	435.31	56.48	90.23	49.89	38.87
SEm±	3.17	9.75	3.75	15.94	1.78	2.84	1.53	1.17
CD (p=0.05)	9.18	28.17	10.83	46.04	5.12	8.20	4.41	3.39

with application of biochar @ 8, 6, 4 and 2 t ha^{-1} (T_5, T_6, T_7 and T_8) recorded lower manganese content in grain and straw as compared to combined application of levels of biochar and FYM.

Grain and straw zinc content increased with increased levels of CS-biochar and FYM. Application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF recorded significantly higher zinc content in grain and straw (56.48 and 90.23 mg kg^{-1}, respectively) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (56.13 and 87.17 mg kg^{-1}, respectively), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (55.17 and 83.57 mg kg^{-1}, respectively) and rest of the treatment were significantly on par with each other. However, lower zinc content recorded in absolute control treatment (37.33 and 67.7878 mg kg^{-1}, respectively).

Significantly higher copper content in grain was recorded in application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (49.89 mg kg^{-1}) followed by CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (48.00 mg kg^{-1}), CS-biochar @ 4 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (47.26 mg kg^{-1}) which was on par with CS-biochar @ 2 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF (47.12 mg kg^{-1}) as compared to recommended dose of fertilizer treatment (38.23 mg kg^{-1}). However, application of CS-biochar @ 8 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF and CS-biochar @ 6 t ha^{-1} + FYM @ 10 t ha^{-1} + RDF recorded significantly higher copper content in straw (38.87 and 35.63 mg kg^{-1}) over rest of the treatments as compared to recommended dose of fertilizer treatment (26.64 mg kg^{-1}) and remaining treatments were on par with each other.

Increase in primary, secondary and micronutrients content in different plant parts at different growth stages, grain and straw of aerobic rice was recorded with the application of combined application of coconut shell biochar (6 to 8 t ha^{-1}) and FYM (10 t ha^{-1}) with RDF treatments. This could be attributed to the fact that besides acting as an amendment, biochar also provides all the essential nutrients in sufficient quantities for better uptake. Results of enhanced uptake of nutrients due to the application of biochar to soil has shown definite increases in the availability of major cations and phosphorus as well as in total nitrogen and phosphorus concentrations. Van Zwieten *et al.* (2010) reported similar effect of biochar on NPK content in which it was observed that application of biochar significantly increased uptake of plant nitrogen. Chan *et al*. (2008) also reported high NPK uptake of radish plants grown in biochar amended soils. This might be due to application of biochar which serves as store house of several macro and micronutrients and were released during the process of mineralization. In addition to release of plant nutrients from the organic matter, the organic acids formed in the decomposition process also release the native nutrients in soil and increased the availability to plants. Similar results were recorded by Angst and Sohi (2013).

CONCLUSION

The results of present study shows that yield and nutrient content of aerobic rice crop increased with increase in biochar dose and Farm Yard Manure (FYM) with recommended dose of NPK fertilizers compared to low dose of biochar and alone application of biochar. The coconut shell biochar is a high C:N ratio organic material, that could be reduced by the application of FYM. Since, FYM is a good source of microorganisms and hastens the better mineralization rate and increased the efficiency of biochar in soil. Overall the study confirmed that necessity of combined application of biochar, FYM and chemical fertilizers for higher yield and nutrient content reflecting and confirming the improved nutrient availability to crop.

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